MEMO
June 10, 2015

From Mark A. Reis, PhD, PE
(clarifications Ing. Goebel)

GTKW Germany Geothermal Power Plant and Nuclear Waste Disposal

Siggi:

Scope of Work

I had a telephone call with Ing. Goebel this morning. We discussed the GTKW DBD project in detail. It is a complicated building project and I hope I got most of the facts correct. Am researching drilling options for the project now. I will provide updates as they are completed. I intend to make some sketches of the options and present them with the Drill Table that Ing. Goebel is anxious to receive. At this point, I do not see any reason why we cannot drill the wells (the boreholes) as requested. However, I want to research options that would make the drilling options more efficient. And to ensure the big diameters.

The Project has three distinct phases.

Nuclear Disposal Wells: Drill a 1.2 m wellbore to 2.550 meters which is approximately 600 meters into the rock salt. Continue drilling from 2.550 m to 3.300 m using solution mining techniques, underreamer tools and drill a diameter 3.2 m nuclear disposal chamber. Plans are to drill a total of 12-15 disposal boreholes in a circle around the surface facility. Surface casing will be set at 750 m and cemented to surface to protect possible ground water aquifers. The wellbores will be deviated at 5 degrees from vertical. When a section is completely full of radioactive waste, the borehole will be sealed in a special way using a combination of Mg-O cement, sand, clay, asphalt plugs and Bentonit all the way to surface. Complete sealing of the wellbore is essential.

Production Geothermal Wells: Drill a vertical 2.027 m wellbore of 1.2 m diameter. Run and set 2.027 m of steel tube casing and cement. This will provide a mono-bore for the production of heated Carbon-Dioxide to the surface facilities for use in electric generation. The next section of the hole, the Caverne will be operated by a local contractor with over 460 Carverne well experience in the area. This section will consist of a 330 m cavern manufactured using solution drilling techniques. This 440.000 m2 Cavern will provide the storage area for re-circulated CO_2 liquid returning from the surface generator. The waste heat and the geothermal heat will bring the CO2 up to +48°C daily. Estimated bottom-hole-pressure is 140 bar (2030 psi) at +48° C. (CO2 uses as a pressure transfer medium within GTKW)

Injection Geothermal Wells: Drill a 2.146 m wellbore to the bottom on the solution cavern for the return CO_2 liquid. The wellbore will be cased to surface. Current plans are to drill a 412 m nearly horizontal wellbore to a point 105 m from the surface. At this point, the wellbore will be drilled at a 5° angle to Total Depth. This requires the construction of a 105 m vertical shaft to this juncture in order to connect the casing pipe. I recommend looking at a build-and-hold type directional approach. The limits as to wellbore diameter required investigation. If the wellbore diameter is a problem, then optionally two smaller wellbore can be drilled into the bottom of the salt chamber. This would be in a "V" type pattern.

Exploration Wells: Because of the risks involved with the project, 3 to 6 exploration boreholes will be drilled to deeper then the salt basement of 5.500 m. All sections of the hole will be cored to determine

geological properties. This should be a standard well program with the ability to provide 8" OD core-head and 5 inch cores. A standard program would could be:

- 20" conductor pipe set at 30 m.
- Drill a 17-1/2" Hole and set 13-3/8" casing at 500 m to cover the ground water zones.
- Drill 12-1/4" Hole and set 9-5/8" casing at the top of the salt at 2100 m
- Drill an 8-1/2" hole thru the salt sections using a salt saturated mud.

Action Items:

Determine the various techniques in order to drill the 1.2 m (47") Wellbores. The use of dual inner-outer barrel drill pipe for reverse circulating drilling. The technical limits of conventional drilling and hole-opening technology as related to wellbore diameter sizes. The drilling options for maintaining a constant build rate of 5° from vertical.

I had an initial conversation with Al Nackerud with Harvest Tool Company in Denver. They have a 1.5 m jet cavity Under- Reamers that has performed well in solution mining. Per our discussion, their tool can be modified to create a 3.2 m cavern. The critical parameter is the drill pipe size. We will probably use a large diameter, reverse circulating drill string for the job.